Fermilab

Particle Physics Division

12-01-01

Mechanical Department Engineering Note

Number: MD-Eng-219 Date: January 19, 2010

Project: DES TELESCOPE SIMULATOR

Project Internal Reference:

Title: NW Platform Diving Board and Flipper

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Key Words: DECAM, DES, TELESCOPE SIMULATOR, NW PLATFORM

Abstract/Summary:

Two slide-out platforms are attached to the NW Platform in order to permit access to the telescope's imager and filters. Since these sliding platforms cantilever out from the main platform when extended, they mimic a "diving board" and have been nicknamed as such. A smaller rectangular platform is cantilevered off the inside edge of each diving board to permit closer access to the telescope.

The deflection of the existing diving boards was at an uncomfortable level. An attempt to limit this deflection was made by adding another longitudinal support tube down the center of each diving board. Although this reduced the bending stress so that these platforms conform to OSHA code loading requirements using AISC allowable strength design, the deflection still was greater than desired.

A slide-out support tube that is attached to the underside of the NW Platform was added to the original design to further limit the deflection. Also, the safety railing was redesigned to conform to OSHA requirements.

Applicable Codes:

Manual of Steel Construction, ASD, Ninth Edition, American Institute of Steel Construction, Inc. 1989

Occupational Safety and Health Standards for Industry, (29 CFR Part 1910), Commerce Clearing House Inc., 1989

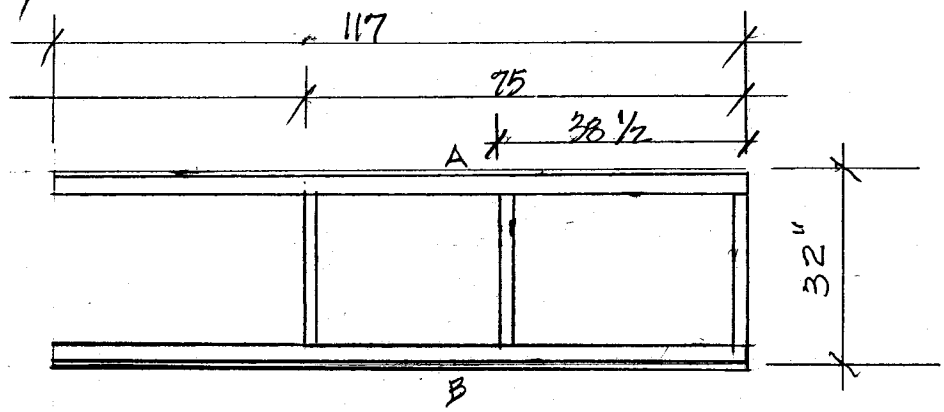
PLATFORM EXTENSION:

DESIGN LOADS:

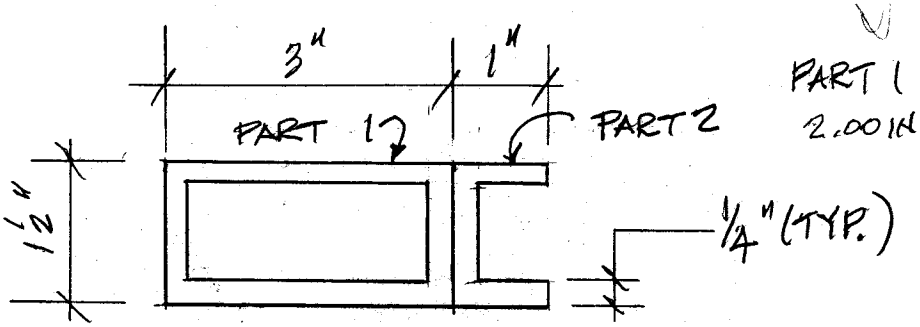
OSHA — MEDIUM = 50#/FT²

1 OR MORE 200# PERSONS + 50# EQUIPMENT

ANSI/ASCE — 60/FT² TAB. 2 ELEVATED PLATFORM



SIDE RAILS A & B SECTION:



AREAS

PART 1	PART 2
2.00 IN²	0.75 IN²

PART 1 = 3 × 1 1/2 × 1/4 TUBE

PART 2 = 2 1/2 × 1 1/2 × 1/4 CUT AS SHOWN

$$I_{xx_1} = \frac{bd^3 - b_1 d_1^3}{12} = \frac{3(1\tfrac{1}{2})^3 - 2.5(1)^3}{12} = 0.635\ \text{IN}^4$$

$$I_{xx_2} = \frac{b(d^3 - d_1^3)}{12} + \frac{b_2 d_2^3}{12} = \frac{1(1.5^3 - 1^3)}{12} + \frac{0.25(1)^3}{12} = 0.219\ \text{IN}^4$$

$$\text{TOTAL} = 0.635 + 0.219 = 0.854\ \text{IN}^4$$

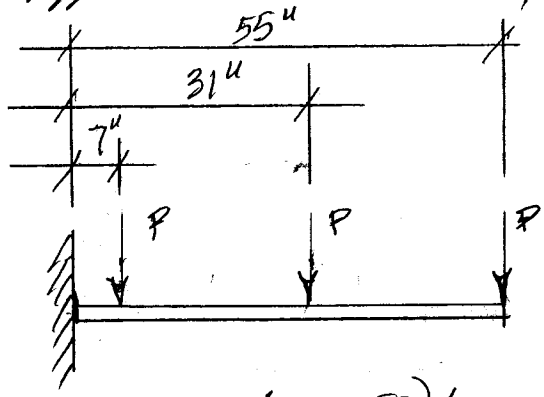
FOR 55" SPAN:

UNIFORM LIVE LOAD DEFLECTION:

$$w = 50\#/\text{FT}^2 / 144\ (32/2) = 5.56\#/\text{IN}$$

$$\Delta = 5.56(55)^4 / 8(29{,}000{,}000)(0.854) = 0.26''$$

CONCENTRATED LIVE LOAD:
ASSUME 3 200# PEOPLE W/ 50# EQUIPMENT EACH:



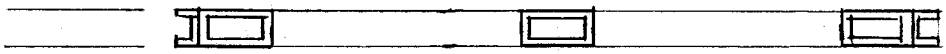
LOADS PER SIDE $= (200+50)/2 = 125^{\#}$ EA

$$\text{TOTAL } \Delta = \frac{125(7)^2}{6(29000000)(0.854)}(3(55)-7) + \frac{125(31)^2}{6(29,000,000)(0.854)}(3(55)-31)$$
$$+ \frac{125(55)^2}{6(29,000,000)(0.854)}(3(55)-55)$$
$$= 0.004 + 0.108 + 0.280$$
$$= 0.392''$$

$$l/180 = 55/180 = 0.306'' < 0.392'' \text{ N.G.}$$

TRY ADDITIONAL TUBE DOWN CENTER

$$I_{xx} = 3(0.635) + 2(0.219)$$
$$= 2.343 \text{ IN}^4$$

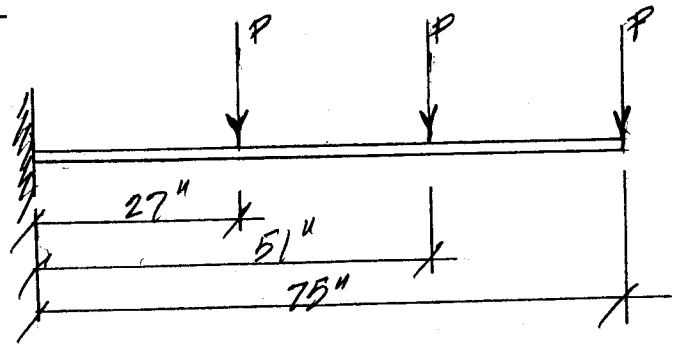


$$\text{TOTAL } \Delta = \frac{250(7)^2}{6(29,000,000)(2.343)}(3(55)-7) + \frac{250(31)^2}{6(29,000,000)(2.343)}(3(55)-31)$$
$$+ \frac{250(55)^3}{3(29,000,000)(2.343)}$$
$$= 0.005 + 0.079 + 0.204$$
$$= 0.288'' < 0.306'' \text{ OK}$$

Δ DUE TO 50 #/FT² LIVE LOAD:

$$w = (50/144)(32)$$
$$= 11.1 \ \#/IN$$
$$\Delta = \frac{11.1(55)^4}{8(29{,}000{,}000)(2.343)}$$
$$= 0.187 \ IN < 0.306'' \ OK$$

FOR 75" SPAN:



$P = 250^{\#}$

$$\text{TOTAL } \Delta = \frac{250(27)^2}{6(29{,}000{,}000)(2.343)}(3(75)-27) + \frac{250(51)^2}{6(29{,}000{,}000)(2.343)}(3(75)-51)$$
$$+ \frac{250(75)^3}{3(29{,}000{,}000)(2.343)}$$
$$= 0.084 + 0.278 + 0.517$$
$$= 0.833''$$

$$\ell/180 = 75/180$$
$$= 0.417 < 0.833 \ \underline{NG}$$

ALLOWABLE STRESS:

CHECK SIDE MEMBERS FOR COMPACT SECTION

TOP PL $t = 0.1345''$, $b = 5.634''$ (45° FROM BOT. FLANGE)

$$b/t = 5.634/0.1345$$
$$= 42$$

COMPACT LIMIT FROM TAB. B5.1 $= 190/\sqrt{F_y}$
$$= 190/\sqrt{46}$$
$$= 28 < 42 \therefore \text{NOT COMPACT}$$

NONCOMPACT LIMIT $= 238/\sqrt{F_y}$
$$= 238/\sqrt{46}$$
$$= 35 < 42$$

∴ USE SECTION F2.2 $F_b = 0.60 F_y$
$$= 0.60(46) = 27.6 \ KSI$$

PERFORM ANSYS ANALYSIS OF PLATFORM EXTENSION:

CASE 1 GRAVITY + 50 PSF LIVE LOAD

PAGE # THIS CALC

MAXIMUM STRESS

BEAMS = 20,947 PSI < 27,600 PSI OK (P. 16)

PLATE = 20,331 PSI < 27,600 PSI OK (P. 17)

MAXIMUM DEFLECTION = 1.6" > $\ell/180$ = 0.417" (P. 18)

CASE 2 GRAVITY + 2 PEOPLE (SEE NOTE BELOW)

MAXIMUM STRESS

BEAMS = 16,886 PSI < 27,600 PSI OK (P. 19)

PLATE = 18,288 PSI < 27,600 PSI OK (P. 20)

MAXIMUM DEFLECTION = 1.4" > $\ell/180$ = 0.417" (P. 21)

NOTE: IT WAS DECIDED TO LIMIT THE CAPACITY OF THE DIVING BOARD AND FLIPPER TO 2 PEOPLE AT A TIME

SINCE STRESSES ARE BELOW ALLOWABLE BUT DEFLECTIONS ARE OVER RECOMMENDED, DESIGN A RETRACTABLE SUPPORT AT FREE EDGE OF FLIPPER TO LIMIT DEFLECTION. SEE PAGE 10 FOR THIS CALCULATION.

PLATFORM EXTENSION-EXTENSION (FLIPPER)

PLATFORM EXTENSION-EXTENSION SIZE = 40"×15"

PLATFORM WT. 1"×1"×0.120 TUBES = 1.436 #/FT

FRAME
2(40)(1.436/12) = 9.57#
3(13)(1.436/12) = 4.67#

FLOOR PLATE (10 GA)
15(40)/144 (5.625) = 23.44#

CARPET
15(40)(144)(1.0) = 4.17#

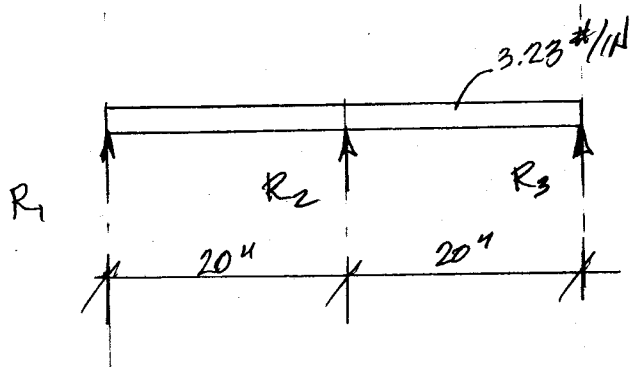
41.85# SAY 50#

UNIT LOAD = 50/(15×40) = 0.083 #/IN²

LIVE LOAD = 50#/FT²/144 = 0.347 #/IN²
OR (200#+50#) @ EDGE (2 REQ'D)

CASE 1 UNIFORM DEAD + LIVE LOAD
w = 0.083 + 0.347
= 0.430 #/IN²

EDGE LOAD = (15/2)(0.430)
= 3.23 #/IN



$R_1 = R_3 = \frac{3}{8} w l$
$= \frac{3}{8}(3.23)(20)$
$= 36.34\#$

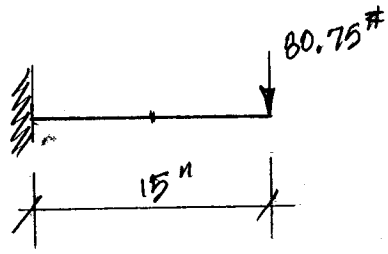
$R_2 = 1.25 w l$
$= 1.25(3.23)(20)$
$= 80.75\#$

$M_{MAX} = -\frac{1}{8} w l^2 = -\frac{1}{8}\, 3.23(20)^2$
$= -161.5\#\text{-IN}$

$c = d/2 = 1/2$

$f_b = 161.5(0.5)/0.055$
$= 1468$ PSI ok

PERPENDICULAR TUBES:
CENTER TUBE TAKES MOST LOAD



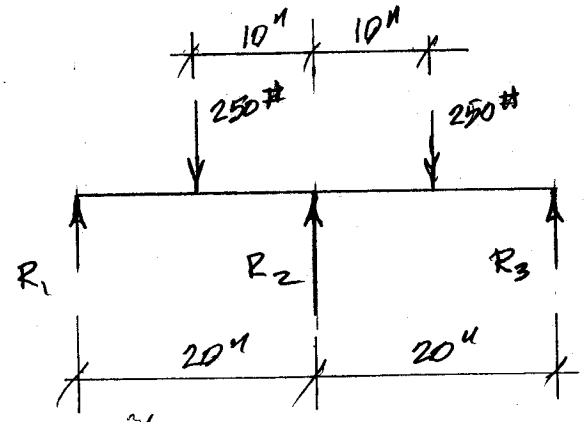
$M = 80.75(15)$
$= 1,211$ #-IN

$f_b = 1,211(0.5)/0.055$
$= 11,011$ PSI OK

$\Delta_{MAX} = Pl^3/3EI = \frac{80.75(15)^3}{3(29,000,000)(0.055)}$
$= 0.057"$

$l/180 = 15/180 = 0.083" > 0.057$
OK

CASE 2 CONCENTRATED LIVE LOADS



$R_1 = R_3 = 5/16\,P$
$= 5/16\,(250)$
$= 78.125$#

$R_2 = 1.375P$
$= 1.375(250)$
$= 343.75$#

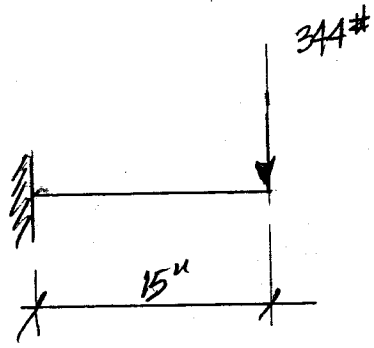
$M_{MAX} = -\overset{3/16}{5/32}\,Pl = -5/32\,(250)(20)$
$= 937.5$ #-IN

$f_b = 937.5(0.5)/0.055$
$= 8523$ PSI OK

Δ (ONE LOAD EA. SPAN) $= 0.015\,Pl^3/EI = \frac{0.015(250)(20)^3}{29000000(0.055)}$
$= 0.019"$

$l/180 = 20/180 = 0.11"$
> 0.019 OK

PERPENDICULAR TUBES
CENTER TUBE TAKES MOST LOAD

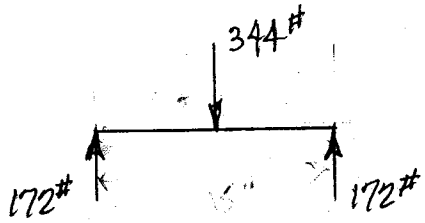


$M = 344(15)$
$= 5160$ #-IN

$f_b = 5160(0.5)/0.055$
$= 46{,}909$ PSI NG

$\Delta_{MAX} = PL^3/3EI = \dfrac{344(15)^3}{3(29{,}000{,}000)(0.055)}$
$= 0.24" > 0.083"$
NG

TRY SUPPORT UNDER FREE LONG EDGE:



$M = Pl/4$
$= 344(15)/4 = 1290$ #-IN

$f_b = 1290(0.5)/0.055$
$= 11727$ PSI ok

$\Delta_{MAX} = \dfrac{PL^3}{48EI}$
$= \dfrac{344(15)^3}{48(29{,}000{,}000)(0.055)}$
$= 0.015" < 0.083"$ ok

∴ USE EXTERNAL SUPPORT.

CONNECTION TO PLATFORM EXTENSION

TOTAL LOAD:

DEAD LOAD:

TUBES: $2(40/12) = 6.67'$
$3(13/12) = 3.25'$
$9.92'$ SAY $10'-0$

TUBE WT. = 1.436 #/FT
PLAT WT. = 5.625 #/FT²

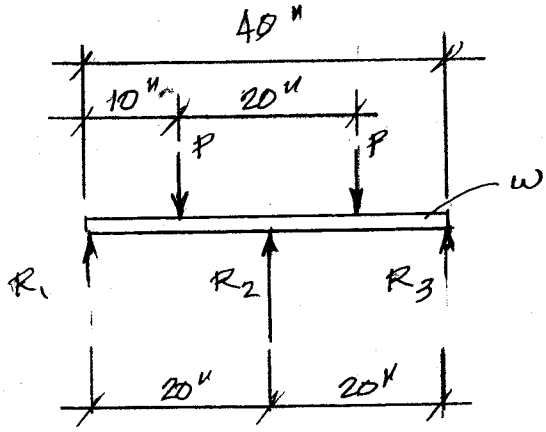
$10.0(1.436) = 14.4$ #

PLATE $(15 \times 40)/144 \times 5.625 = 23.5$ #

TOTAL LOAD $= 14.4 + 23.5$
$= 37.9$ # SAY 40 #

LIVE LOAD = 2 - 200# PERSONS + 50# EQ. EQUIPMENT

TOTAL LOAD ON END TUBE:



$P = 250\#$

$w = 40/15(40) \times \frac{15}{2}$

$= 0.50\#/IN$

$R_1 = R_3 = 5/16 P + 3/8 w l$

$= 5/16(250) + 3/8(0.5)(20)$

$= 78.125 + 3.75$

$= 81.875\#$

$R_2 = 1.375 P + 1.25 w l$

$= 1.375(250) + 1.25(0.5)(20)$

$= 343.75 + 12.5$

$= 356.25\#$

$M_{TUBE + PLATE}$:

$M_{MAX} = 5/32 PL + 1/8 w l^2$

$= 5/32(250)(20) + 1/8(0.50)(20)^2$

$= 975.5 + 25$

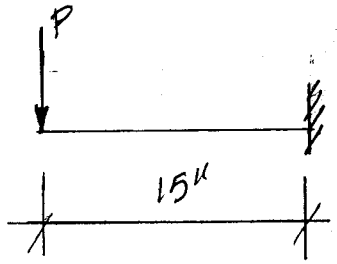
$= 962.5\ \#\text{-IN}$

$f_b = \frac{962.5(0.721)}{0.109}$

$= 6{,}367$ PSI OK

MIDDLE CONNECTION:

$P = 356.25\#$



CENTER:

$M = Pl$

$= 356.25(15)$

$= 5344\ \#\text{-IN}$

END

$M = 82(15)$

$= 1230\ \#\text{-IN}$

TUBE SECTION = 1" HIGH

BOLT SHEAR @ TOP & BOTTOM OF CONNECTION PLATES:

$5344\ \#\text{-IN}/1\text{IN} = 5344\#$ (MIDDLE)

$1230\ \#\text{-IN}/1" = 1230\#$ (ENDS)

FOR 5/8" ϕ BOLTS:
ALLOWABLE SHEAR = 3.1K (AISC TAB. 1-D P. 4-5)

MID – 5344/3100 = 1.7 ∴ 2 BOLTS REQUIRED

USE 3 BOLTS, ALLOW SHEAR = 3(3100)
= 9300# > 5344#

END 1230/3100 = 0.397 ∴ 1 BOLT REQUIRED <u>OK</u>

USE 2 BOLTS, ALLOW SHEAR = 2(3100)
= 6200# > 1230#
<u>OK</u>

CONNECTION PLATES:

COMBINED SHEAR & TENSION MIDDLE CONN. (MOST LOAD)

TENSION = 5344#

$f_t = 5344/6(3/8)$
$= 2375$ psi

$F_T = 0.45F_y$
$= 0.45(36{,}000)$
$= 16{,}200$ psi

SHEAR = 356#

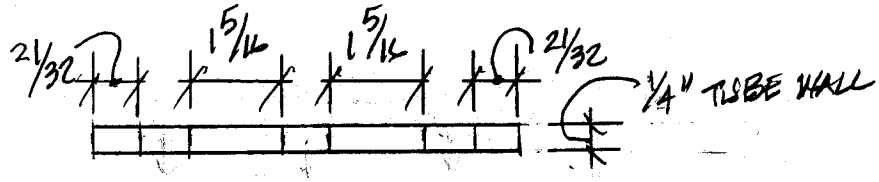
$f_v = 356/6(3/8)$
$= 158$ psi

$F_V = 0.40(36{,}000)$
$= 14{,}400$ psi

COMBINED: $f_t/F_T + \frac{f_v}{F_V} \overset{?}{\leq} 1$

$2375/16{,}200 + 158/14{,}400 = 0.158$
< 1.0
<u>OK</u>

TENSION ON TUBE @ NET AREA BETWEEN BOLTS



$A = 2(21/32(1/4)) + 2(15/16(1/4))$
$= 0.9844$ in²

$F_T = 0.45(46)$
$= 20.7$ KSI $= 20{,}700$ psi

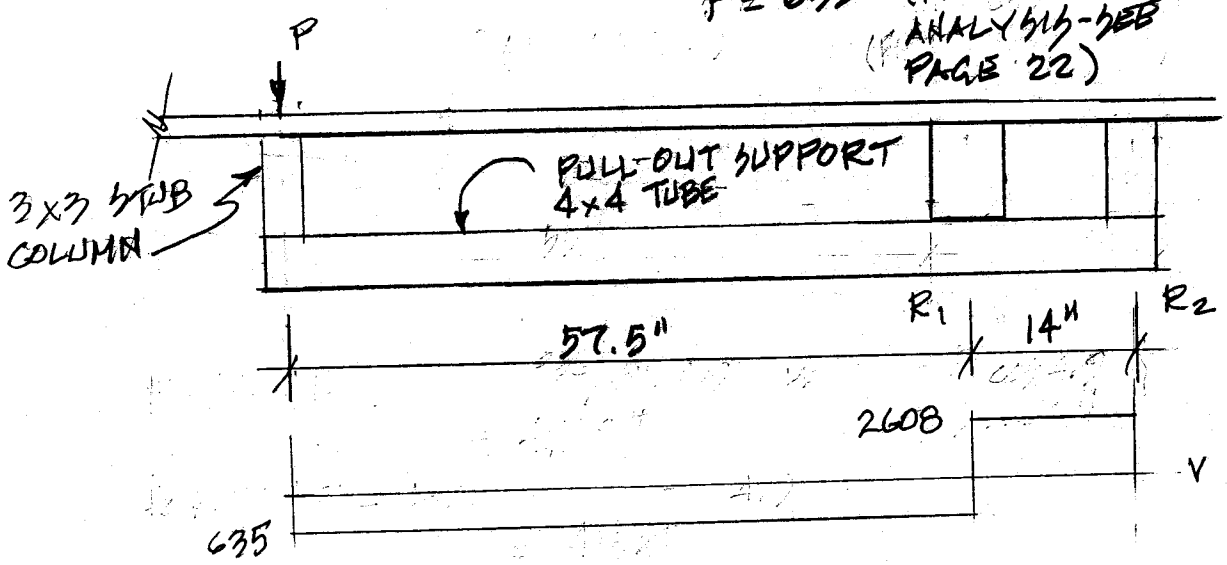
$f_T = 9300/0.9844$
$= 9448$ psi $< 20{,}700$ psi <u>OK</u>

TENSION ON CONNECTION PLATE @ TAPER TO 0.1345" THICKNESS:

$$A = 2(24/32(0.1345)) + 2(1\tfrac{5}{16}(0.1345))$$
$$= 0.530 \text{ IN}^2$$
$$f_T = 9300/0.530$$
$$= 17{,}547 \text{ psi} < 20{,}700 \text{ psi} \quad \underline{\underline{ok}}$$

PULL-OUT SUPPORT FOR FLIPPER:

P = 635# (FROM ANSYS ANALYSIS - SEE PAGE 22)



$$R_1 = (57.5+14)(635)/14 = 3243^{\#} \uparrow$$
$$R_2 = (57.5)(635)/14 = 2608^{\#} \downarrow$$
$$M_{MAX} = 635(57.5) = 36513 \text{ \#-IN}$$

TRY 4x4x1/4 TUBE:

$A = 3.59 \text{ IN}^2$ $I = 8.22 \text{ IN}^4$
$S_x = 4.11 \text{ IN}^3$ $r = 1.51 \text{ IN}$ $F_y = 42 \text{ KSI}$

CHECK FOR COMPACT SECTION (TABLE B5.1 p 5-36)

$$b/t = 4.0/.25 = 16$$
$$190/\sqrt{F_y} = 190/\sqrt{42} = 29 > 16 \therefore \text{ MEMBER IS COMPACT}$$

FROM F3.1.1 (P. 5-48)

$F_b = 0.66\ F_y$ (EQ: F3-1)
$= 0.66(42)$
$= 27.7$ KSI

L_c MUST BE LESS THAN $1200(b/F_y) = 1200(4/42)$
$= 114''$

$57.5'' < 114''$ OK

$f_b = M/S = 36513/4.11$
$= 8884$ PSI $< 27{,}700$ PSI OK

SHEAR:

$h/t_w \overset{?}{\leq} 380/\sqrt{F_y}$ (P 5-49)

$4/2(0.25) \overset{?}{\leq} 380/\sqrt{42}$

$8 < 59$

$\therefore F_v = 0.40 F_y$ (EQ F4-1)
$= 0.40(42)$
$= 16.8$ KSI

$f_v = 2608/3.59$
$= 726$ PSI $< 16{,}800$ PSI OK

USE HSS 4x4x1/4

CHECK WELD ON 5x5x1/4 CRADLE TUBE:

MAX DOWNWARD LOAD = 3243#

FOR E70XX ELECTRODES:
ALLOW. LOAD PER INCH = $0.3(70)(.707)(3/16)$
$= 2.78^k$
$= 2780$ #

MAXIMUM LENGTH OF WELD PER SIDE ON EXIST. 6x6 PLATFORM TUBE = $6'' - (1'' + 0.5) = 4.5''$

WELD WILL BE ON 2 SIDES, THUS ALLOW. LOAD =
$2(4.5)(2780) = 25{,}020\# > 3243\#$ OK

USE 3/16" WELD

CHECK HSS 3x3x1/4 VERT. SUPORT TUBE:
USE TOP SECTION OF TUBE SINCE 1/2 OF TUBE IS CUT AWAY

FROM IDEAS ANALYSIS: (SEE PAGE 23)

$A = 1.355 \text{ IN}^2$

$I_x = 0.273 \text{ IN}^4$

$I_y = 1.701 \text{ IN}^4$

$r = \sqrt{I/A} = \sqrt{0.273/1.355}$

$= 0.449$

$K = 1.0$

$Kl/r = 1.0(8.0)/0.449$

$= 17.8''$

$C_c = 116.7$ (TABLE 4 P 5-120)

$$F_a = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right]F_y}{5/3 + \frac{3(Kl/r)}{8C_c} - \frac{(Kl/r)^3}{8C_c^3}} = \frac{\left[1 - \frac{(17.8)^2}{2(116.7)^2}\right]42}{5/3 + \frac{3(17.8)}{8(116.7)} - \frac{(17.8)^3}{8(116.7)^3}}$$

$= 24.1 \text{ KSI}$

$f_a = 635/1.355$

$= 469 \text{ PSI} < 24{,}100 \text{ PSI}$ OK

USE HSS 3x3x1/4

NW PLATFORM RAILING

OSHA 1910.23 c p17

POST = 1½" NOM. PIPE

TOP SURFACE OF TOP RAIL 42" ABOVE

DIAMETER(D) OF 1½" X STRONG PIPE = 1.90"

MAX. HORIZ LOAD = 200#

MOMENT = (42" − 1.9") (200)#

= 8020 #-IN

$S = 0.412\ IN^3$ (AISC P1-93)

$f_b = 8020/0.412$

= 19470 psi

CHECK TO SEE IF PIPE IS COMPACT (AISC TAB. B5.1 p 5-36)

$D/t < 3300/F_y$ D = 1.90, t = .20

$D/t = 1.90/.20$ = 9.5 3300/35 = 94

9.5 < 94 ∴ PIPE COMPACT

$F_b = 0.66 F_y$

= 0.66(35)

= 23.1 KSI = 23,100 psi > 19470 psi ok

USE 1½" ϕ DOUBLE STRONG PIPE

FIND MAXIMUM SPAN FOR HORIZ. RAIL:

$M_{MAX} = 23100(0.412)$

= 9517 #-IN

9517 = 200(l)/4

190" = L USE L_{MAX} = 96"

NEW RAIL CONNECTION TO EXISTING BRACKET

EXISTING PIPE = 1.5" OD, 1.26" ID

TRY 1.25" SOLID ROUND BAR INSERT INTO EXIST. PIPE

ROUND BAR PROPERTIES:

$A = \pi(1.25)^2/4$

= 1.227 IN^2

$$S = \pi d^3/32 = \frac{\pi (1.25)^3}{32}$$

$$= 0.192 \text{ IN}^3$$

$$I = \pi d^4/64 = \frac{\pi (1.25)^4}{64}$$

$$= 0.1198 \text{ IN}^4$$

$$f_b = M/S = 8020/0.192$$

$$= 41\,770 \text{ PSI}$$

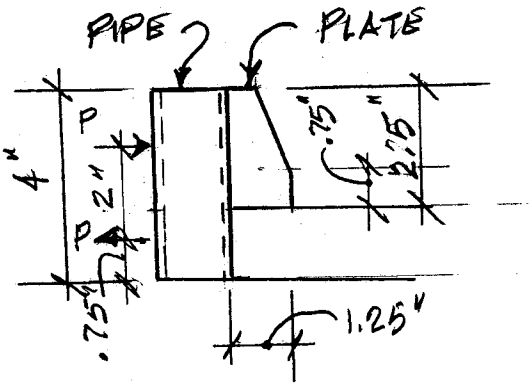
$$F_{y\,REQ'D} = \frac{41{,}770}{0.66}$$

$$= 63\,300 \text{ PSI}$$

USE 4340 ROUND BAR 1 1/4" ϕ $F_y = 69{,}000$ PSI

(McMASTER # 4437T163 (36" LONG)

CHECK WELD CONNECTION TO PLATFORM



$$P = 8020/2$$

$$= 4010\#$$

USING 3/16" WELD, ALLOW LOAD PER INCH $= 0.3(.707)(70 \text{ KSI})(3/16)$

$$= 2.78 \text{ K/IN}$$

TOP LOAD = 4010#

WELD LENGTH = 2.5

$$P_{ALLOW} = 2(2.5)(2.78)$$

$$= 13.9 \text{ K} = 13900\#$$

$$> 4010\# \text{ ok}$$

BOTTOM LOAD = 4010#

WELD LENGTH = 1.5"

$$P_{ALLOW} = 2(1.5)(2.78)$$

$$= 8.34 \text{ K}$$

$$= 8{,}340\# > 4010\# \text{ ok}$$

WELD BETWEEN PLATE & PLATFORM

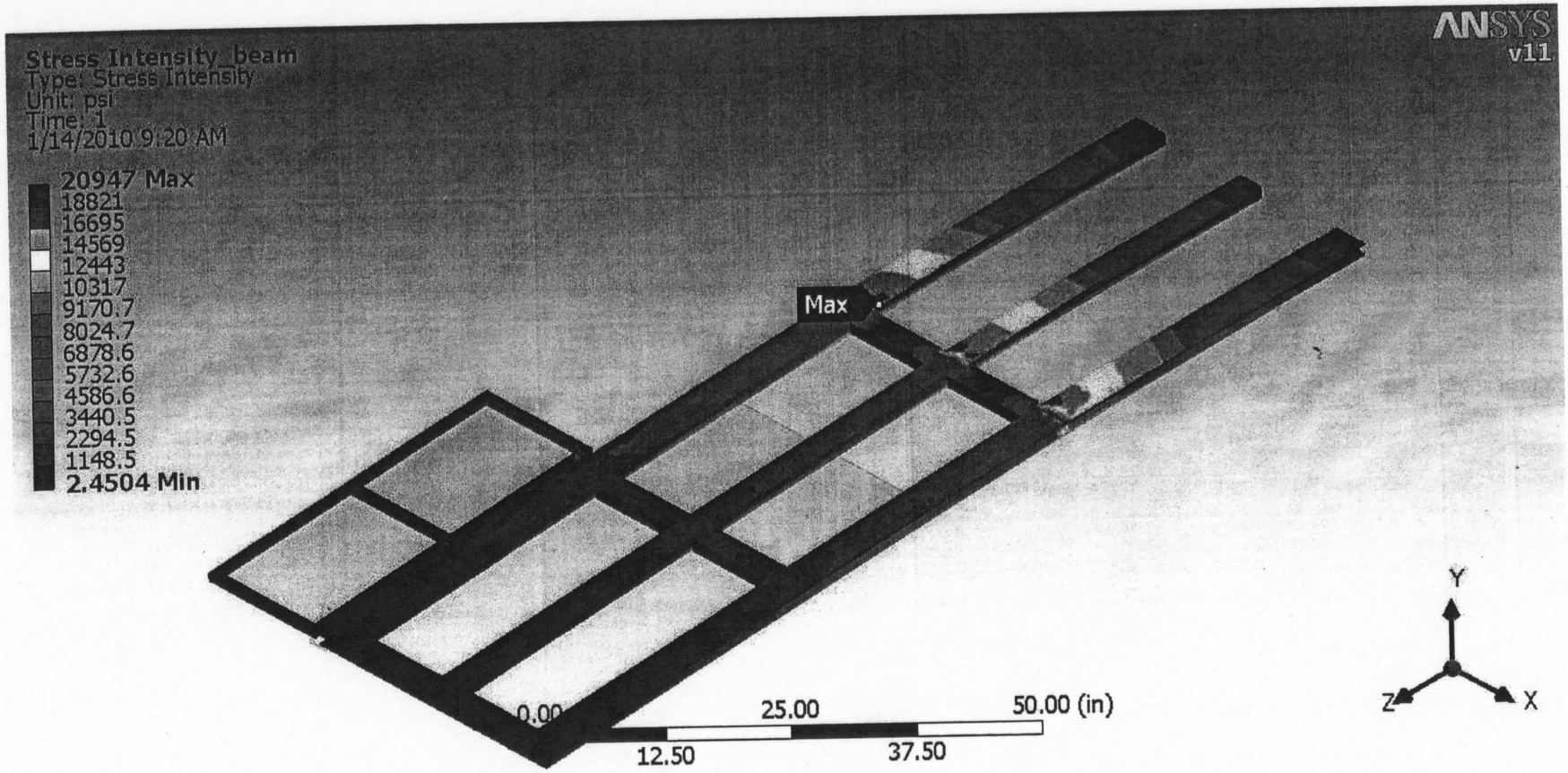
$P = 4010$

$P_{ALLOW} = 2(1.25)(2.78)$

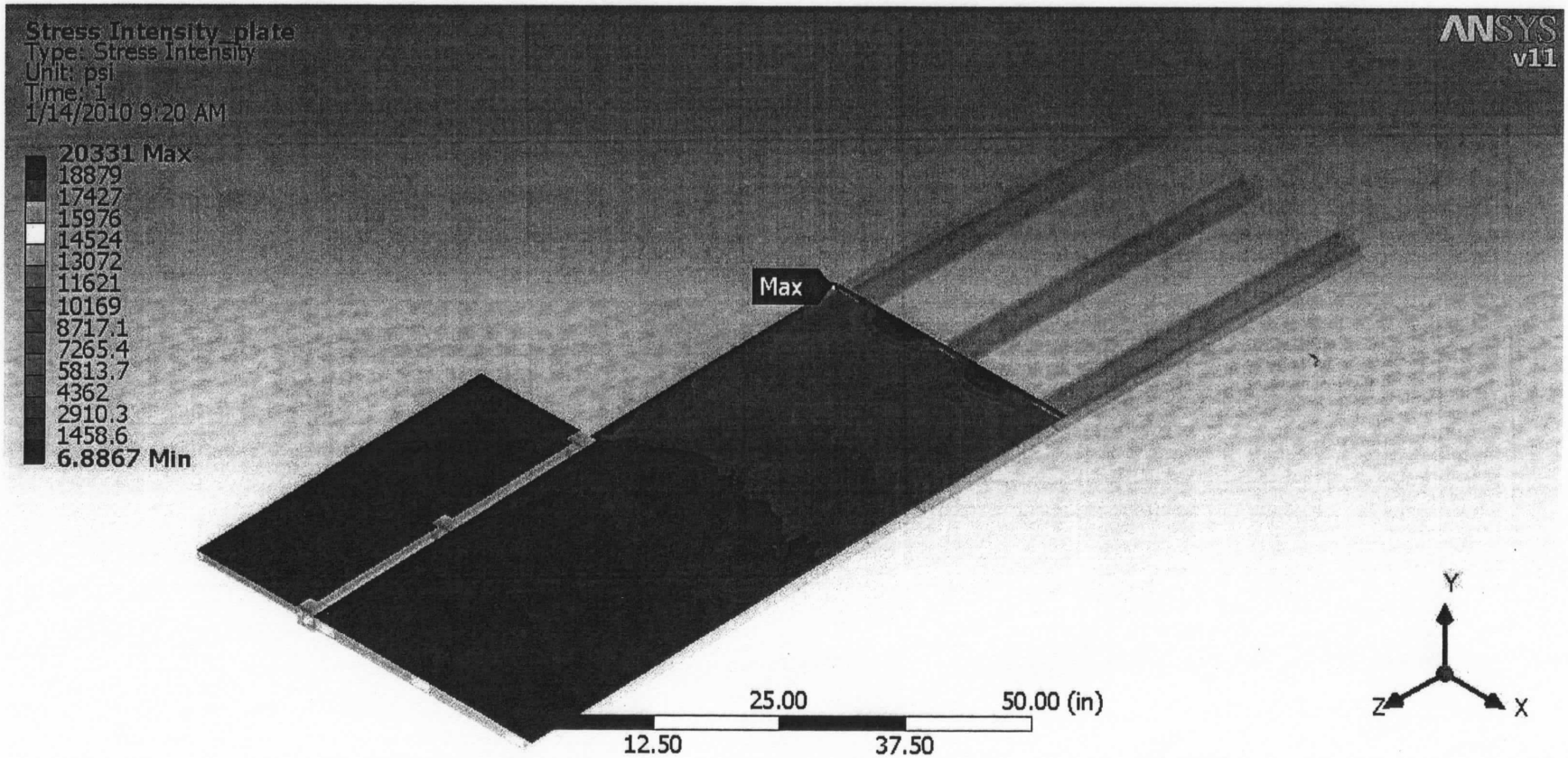
$= 6.95^K$

$= 6950^{\#} > 4010^{\#}$ ok

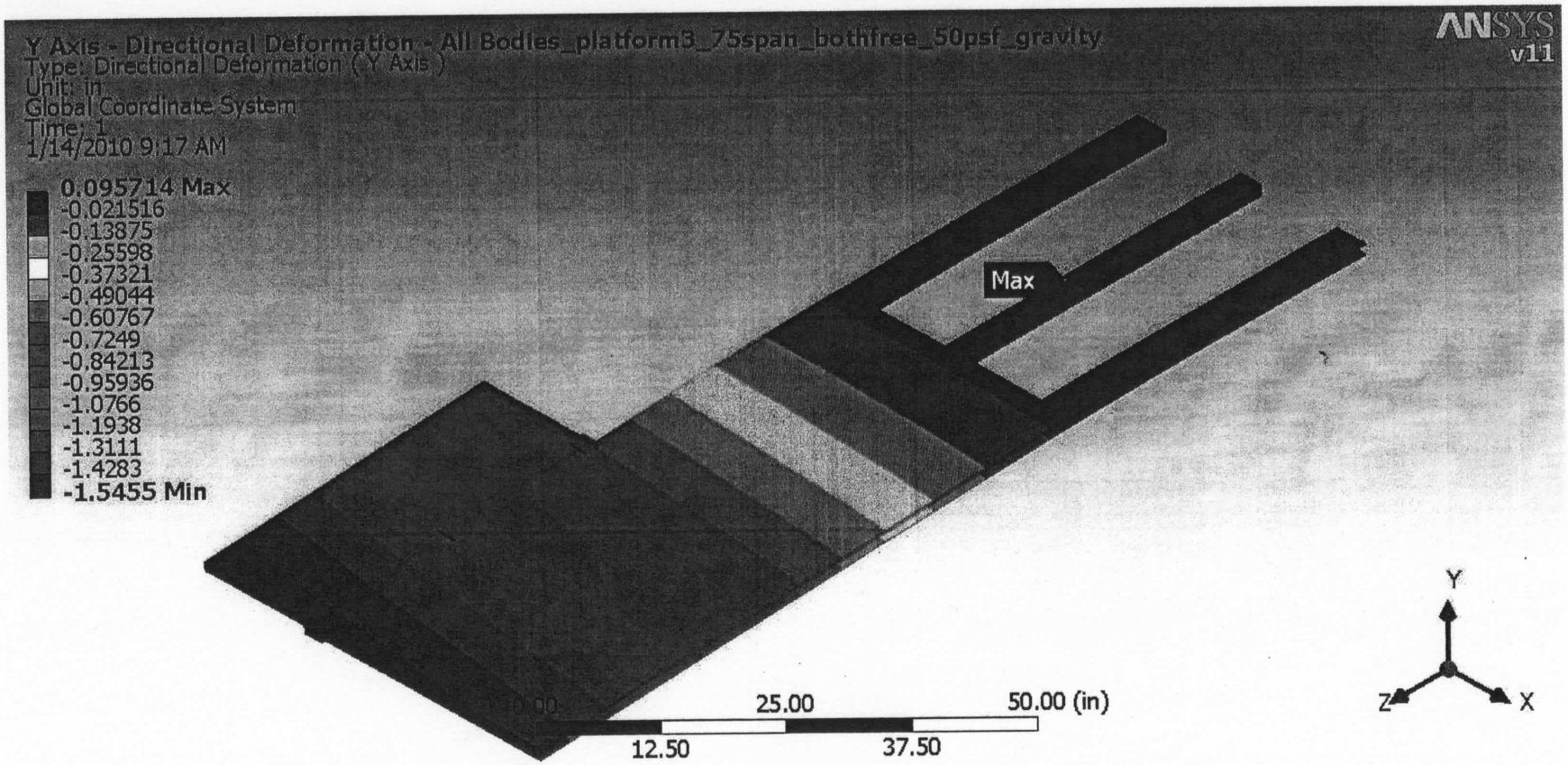
75" SPAN 50PSF + GRAVITY



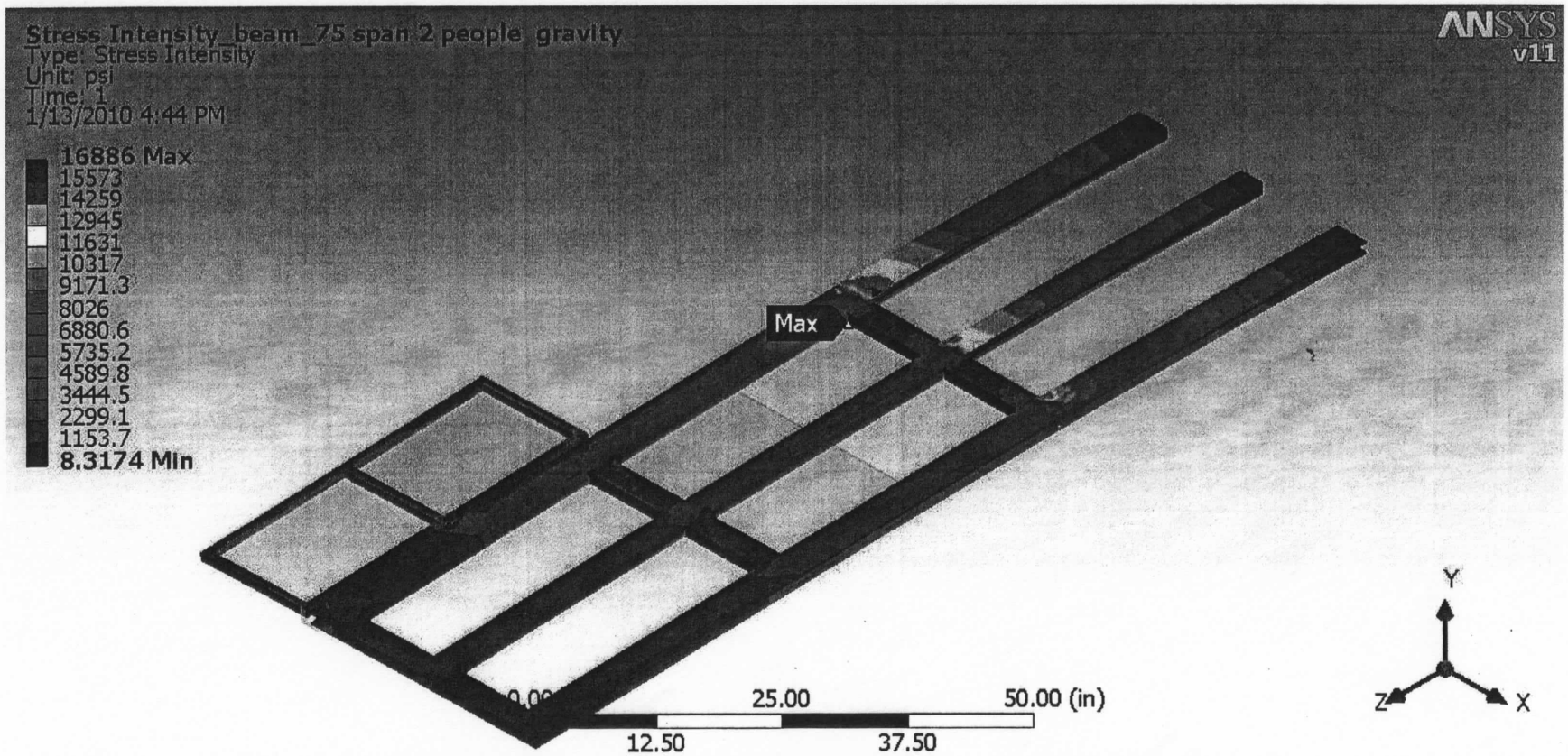
75" SPAN 50PSF + GRAVITY



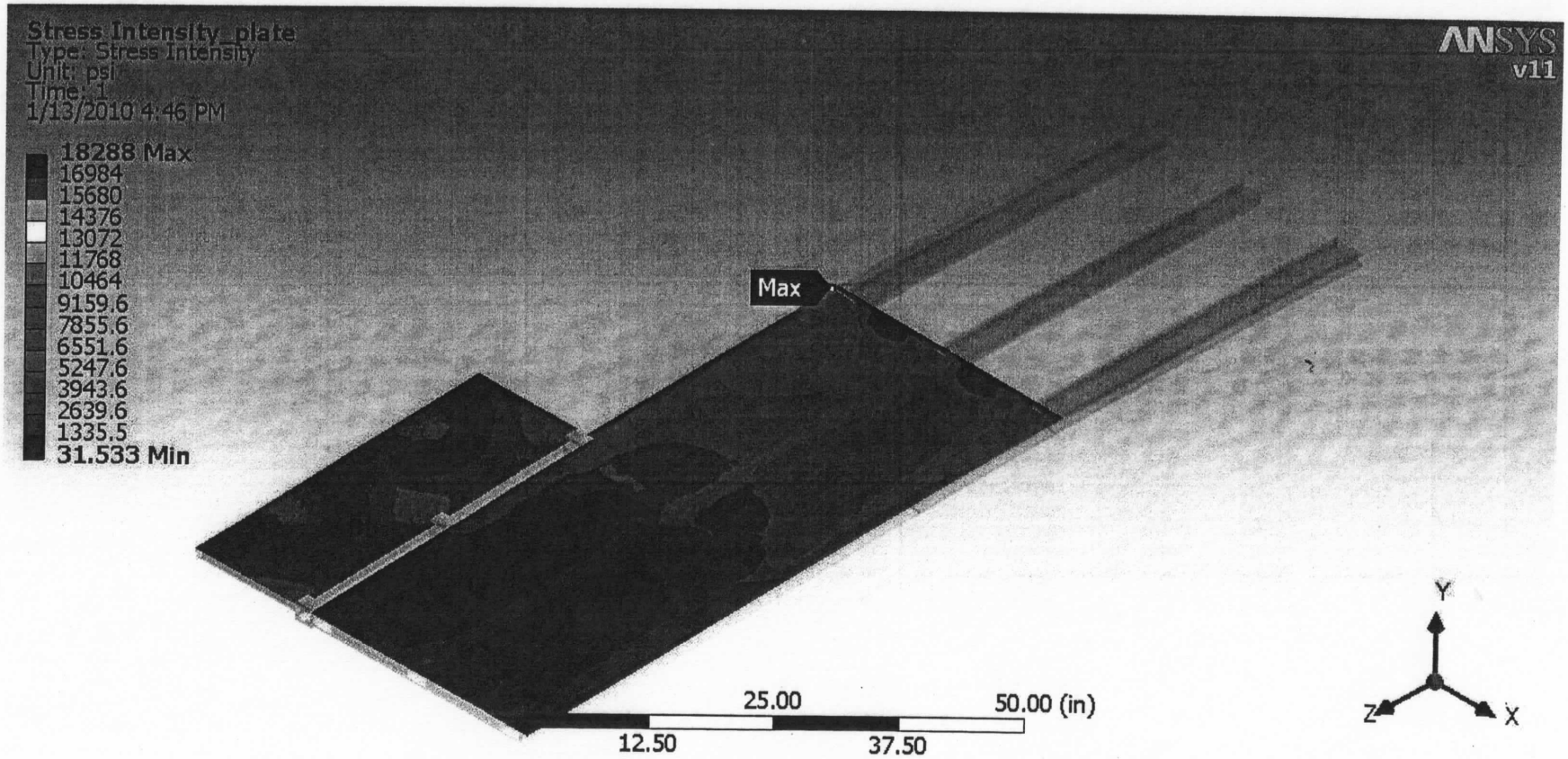
75" SPAN 50PSF + GRAVITY



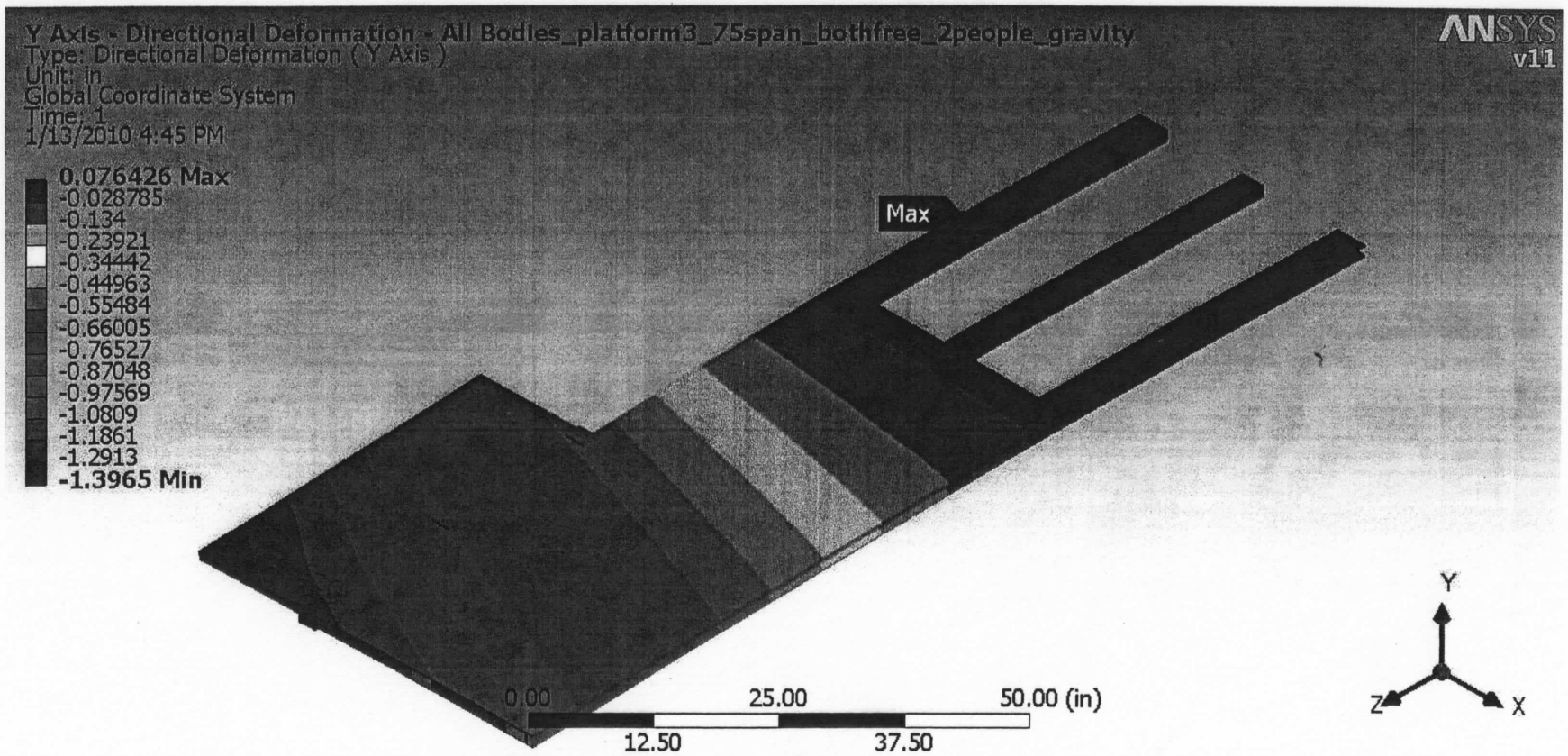
75" SPAN 2 PEOPLE + GRAVITY



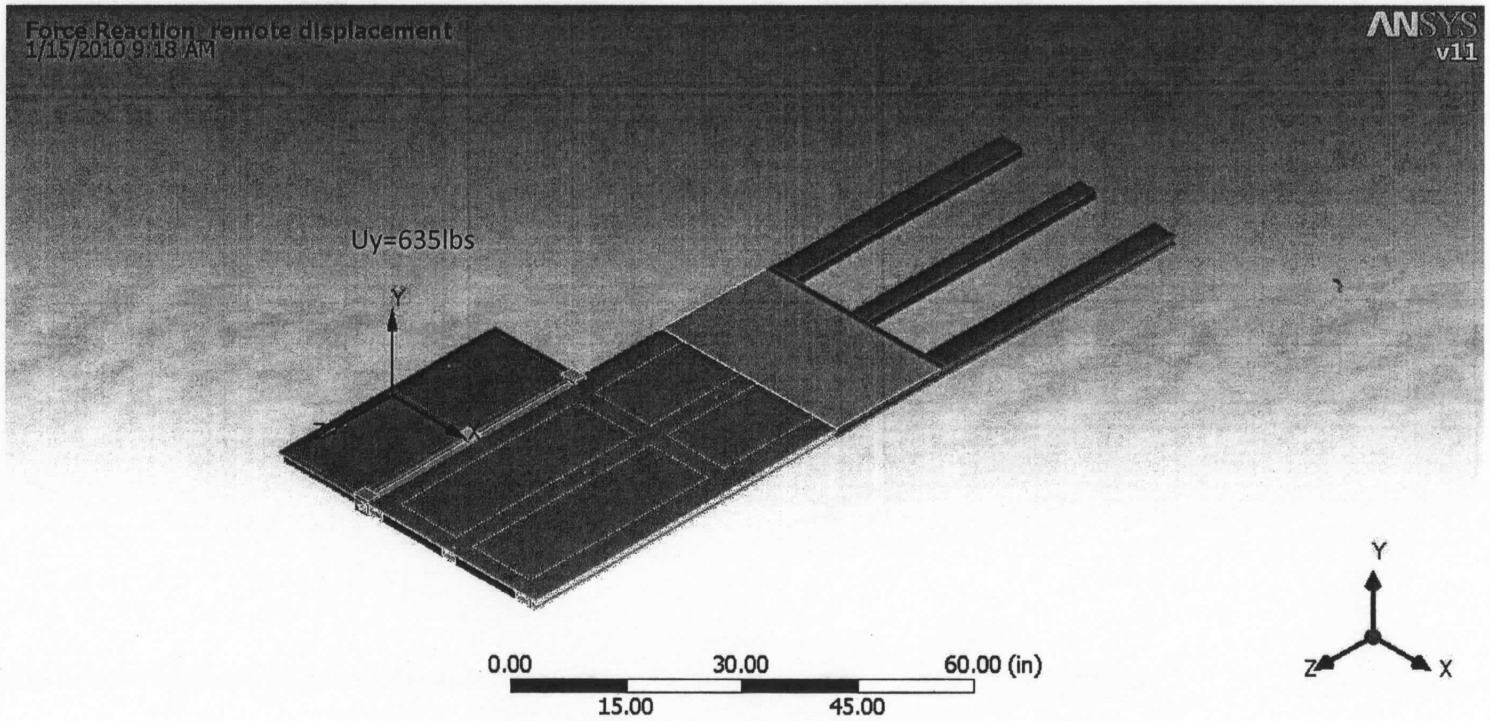
75" SPAN 2 PEOPLE + GRAVITY



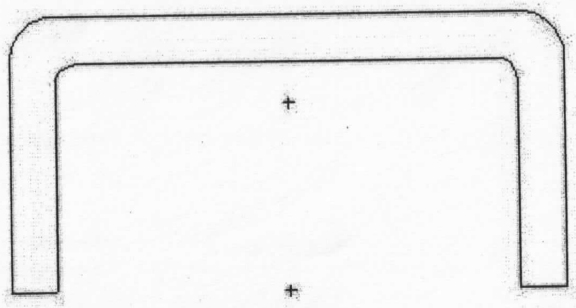
75" SPAN 2 PEOPLE + GRAVITY



REACTION FORCE ANALYSIS WITH ADDITIONAL FLIPPER SUPPORT



IDEAS CUT TUBE SECTION PROPERTIES



Area=1.355e+00
Xcg=-9.731e-17
Ycg=1.027e+00
Ixcg=2.726e-01
Iycg=1.701e+00
Ixycg=0.000e+00
Ixor=1.701e+00
Iyor=1.701e+00
Ixyor=-3.661e-16
Kxcg=4.486e-01